CLAIMS

1. A method of using a focused beam of ions to deposit material onto a target or to remove material from a target, comprising:

extracting ions from an ion source;

forming the ions into a non-Gaussian, shaped ion beam having at a target plane an average current density lower than that of a similar beam without shaping;

providing a target;

directing a jet of working material towards the target; and

directing the ion beam toward the target, the ions in the beam inducing a reaction of the working material to deposit material onto the target or to remove material from the target.

2. The method of claim 1 in which forming the ions into a non-Gaussian, shaped beam comprises:

passing the ions through an aperture; and

forming an image of the aperture onto the target.

3. The method of claim1 in which forming the ions into a non-Gaussian, shaped beam comprises:

passing the ions through an aperture; and

strongly underfocusing the ion beam to produce a uniform current density at the target surface.

4. The method of claim 1 in which forming the ions into a non-Gaussian, shaped ion beam includes forming the ions into a beam having a current greater than that of an unshaped

beam, thereby depositing or removing material faster than an unshaped beam without depleting the working material.

5. The method of claim 1 in which the non-Gaussian, shaped ion beam is characterized in the target plane by a current density profile having a geometric feature with an edge resolution that is similar to that of the beam without shaping, thereby producing features on the target as fine as those produced by an unshaped beam.

6. The method of claim 1 in which directing the ion beam toward the target includes etching or depositing at the target a pattern corresponding to the shape of the ion beam and then stepping the ion beam to repeat the pattern.

7. The method of claim 1 in which forming a focused ion beam includes positioning a straight edge in the path of the ions near the beam center, thereby forming a shaped ion beam having at the target plane a straight edge with high edge resolution and producing on the target a feature having a straight edge.

8. The method of claim 1 in which directing a jet of working material towards the target includes directing a precursor gas and in which the reaction induced by the ion beam includes deposition of a conductive or an insulating material.

9. A focused ion beam system for irradiating a target positioned at a target plane, comprising:

a vacuum system;

an ion beam column positioned in the vacuum system for creating an ion beam for impinging upon a target, the ion beam column including high voltage, beam blanking and

scanning electrodes and producing a non-Gaussian, shaped ion beam having an average current density lower than that of an unshaped beam;

a secondary electron or ion detection and imaging system;

a gas injection system for directing a jet of gas toward the impact point of the shaped ion beam on the target; and

a controller for controlling the shaped ion beam to irradiate an area on the target to initiate a reaction by gas adhered to the target, the reaction etching the target area or depositing a material onto the target area.

10. The focused ion beam system of claim 9 in which low current density is substantially uniform across the shaped beam in the target plane.

11. The focused ion beam system of claim 9 in which the shaped beam is characterized by a current density profile at the target plane and in which the current density profile exhibits at least one geometric feature having a high edge resolution.

12. The focused ion beam system of claim 9 in which the ion beam column includes an aperture and a lens for imaging the aperture upon the target.

13. The focused ion beam system of claim 9 in which the gas injection system includes a precursor gas for depositing a conductive or insulating material.

14. The focused ion beam system of claim 9 further comprising a straight edge positioned in the path of the beam near its center, thereby forming at the target plane an ion beam having a straight edge with high edge resolution that is substantially unaffected by chromatic and spherical aberration.

15. The focused ion beam system of claim 9 in which the ion beam column focuses the ion beam sufficiently beyond the target to provide a shaped ion beam of uniform current density at the target.

16. The focused ion beam system of claim 15 in which the ion beam column is substantially chromatic aberration limited.

17. The focused ion beam system of claim 15 in which the ion beam column includes an aperture having one or more straight edges and produces a beam including at least one sharply defined edges.

18. The focused ion beam system of claim 15 in which the aperture has a straight edge and in which the chromatic aberration portion of the edge resolution of the image on the target is inversely related to the shortest distance of the straight aperture edge from the beam optical axis.

19. A method of producing a shaped ion beam, comprising:

emitting ions from an ion source;

forming an image of the ion source using a first lens, the image being formed substantially at a plane of a second lens;

passing the ion beam through an aperture between the first lens and the second lens; and

forming using the second lens an image of the aperture onto a target surface, thereby producing on the target surface an ion impact area having the shape of the aperture.

20. The method of claim 19 in which forming an image of the aperture includes forming an image having a substantially uniform current density in the target plane.

21. The method of claim 20 in which the substantially uniform current density is reduced from the maximum current density of an unshaped ion beam from a comparable ion column.

22. An apparatus for producing a shaped ion beam, comprising:

an ion source;

a first lens;

a second lens defining a second lens plane, the first lens configured to form an image of the ion source at the second lens plane; and

an aperture positioned between the first and second lens, the second lens configured to form an image of the aperture on a target plane.

23. A method of producing a shaped ion beam, comprising:

emitting ions from an ion source;

forming an ion beam from the emitted ions;

passing the ion beam through an aperture; and

focusing the ion beam onto a focal plane significantly beyond a target plane to produce at the target plane a beam having a diameter or size significantly greater than the diameter that the beam would have at the focal plane and having an edge resolution not significantly degraded from that of the unshaped beam.

24. The method of claim 23 in which the aperture is substantially rectangular.

25. The method of claim 24 in which the aperture comprises a knife edge positioned near the center of the beam thereby forming an ion beam having at the target plane a straight edge with high resolution that is substantially unaffected by chromatic and spherical aberration.

26. The method of claim 24 in which the ion beam has a current density at the target plane significantly reduced from that of a corresponding unshaped beam.

27. The method of claim 24 in which the ion beam has a substantially uniform current density at the target plane.

28. The method of claim 24 in which the focusing of the shaped ion beam is substantially limited by the chromatic aberration of the ion column.

29. An apparatus for producing a shaped ion beam, the apparatus comprising :

an ion source providing ions for forming an ion beam along an optical axis;

an aperture positioned after the ion source and restricting the ion beam;

a lens converging the ion beam to a crossover point substantially beyond a target plane such that the current density of the ion beam at the target plane is substantially uniform.

30. The apparatus of claim 29 in which the aperture comprises a straight edge near the optical axis to substantially reduce aberration.